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## Sustainable development evaluation of urban traffic system

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### Abstract

Sustainable development is one of the themes of the world today. Considering growing urban traffic problems and urban environmental problems, developing sustainable transport is particularly important. Based on the urban traffic sustainable development theory, an evaluation index system of traffic sustainable development is built using analysis method and testing methods of index system. Then an improved entropy method is used to define the weight of index of traffic sustainable evaluation index system, and an evaluation model is built, which provides a new perspective for urban sustainable development research.

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**Keywords:** urban traffic system; sustainable development; index system; evaluation model

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### 1. Introduction

Urban traffic system is an important component of urban socio-economic system, and its sustainable development is the precondition of supporting urban sustainable development. Sustainable development will run through all the aspects of urban traffic system planning, construction, running and management. The purpose of comprehensive evaluation on sustainable development of the urban traffic system is to analyse the degree and level of urban traffic system sustainable development and to know whether the society, economy, resource and environment factors of urban traffic system are in coordinated development relationship.

At the same time, comprehensive evaluation as a method of analysis problems is also necessary for the decision-making layer, it should focus on providing information to solve the contradiction between supply and

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demand for the decision makers instead of the result of comprehensive evaluation. The comprehensive evaluation information needs a set of systematic, complete and feasible theories as support.

## 2. Urban traffic system sustainable development theory

### 2.1. The connotation of urban traffic system sustainable development

In the increasingly serious cases between urban traffic issues and urban environmental issues, sustainable development of traffic is particularly important. From the standard of the World Bank for evaluating the traffic policies and actions, we can see that the connotation of urban traffic sustainable development mainly includes three aspects of sustainability: economic sustainability, social sustainability and environmental sustainability.

China established the "Beijing Declaration: Chinese urban traffic development strategy " is consistent with the ideas about the traffic development policies and planning should meet four criteria. (1)Economic feasibility: under the premise of the total cost of all resource inputs, should give priority to the investment projects of the highest economic return. (2)Financial affordability: formulating traffic system planning and project plans should be based on viable investment and operation strategies. (3)Social acceptability: traffic service should meet the needs of all aspects of society, especially to consider the demand of social low-income residents and the weak. Traffic development should minimize the negative effects on society, and in particular to avoid housing and other commercial and industrial demolition caused by traffic building. (4)Environmental sustainability: should implement actions and countermeasures which have little influence on public health and living environment, and which have low consumption on natural resources.

Its connotation can be understood as the development of urban traffic system should meet the ongoing needs of people's economy and social activities based on effective utilization of resources and be coordinate with the environment.

### 2.2. The operation framework of urban traffic system sustainable development

The essence of urban traffic system sustainable development is the coordination of the interaction relationship between urban traffic system and other systems, the relationship as shown in Figure 1.

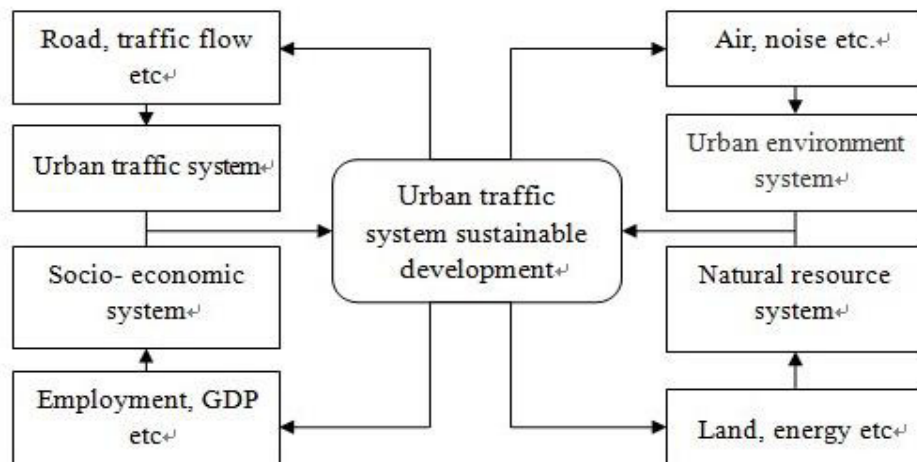


Fig. 1. The operating framework of urban traffic system sustainable development

3. The establishment of evaluation index system of urban traffic system sustainable development

When screening the comprehensive evaluation factors of urban traffic sustainable development, we should analyze not only the specific evaluation objects and evaluation contents, but also using some screen methods to analyze the information embodied in the index system, eliminating unneeded indicators to simplify the index system.

When screening the comprehensive evaluation factors of urban traffic sustainable development, we should consider the purpose of comprehensive evaluation on sustainable development of the urban traffic system, evaluation index data acquisition and information influence for comprehensive evaluation. There are two kinds of preliminary selection methods of the index system, synthesis method and analysis method. Synthesis method is an indicator system constructing method which clusters the existing indexes by certain standards and makes it systematic. Analysis method is a method of making metric objects and metric targets divided into several parts, and gradually subdivided them until every part can be described and achieved by specific statistical indicators. The index system after the preliminary selection may not be satisfied and desirable, often need to improve it. Such as testing each indicators whether can be obtained, those indicators which are unable or difficult to obtain their accurate information or even obtained but need high cost are not feasible. As well as testing calculation methods, calculation range and the correctness of calculation content of each indicator. At the same time, analyze the importance, necessity and completeness of each indicator in index system. We can get 7 indicators of comprehensive evaluation on sustainable development of the urban traffic system, as shown in table 1.

Table 1. The index system of urban traffic system sustainable development comprehensive evaluation

The index system of urban traffic system sustainable development comprehensive evaluation	Density of urban road network
	The total of motor vehicles possession
	Road area per capita
	Average transfer coefficient
	Real GDP per capita
	The growth rate of green area per capita
	The compliance rate of car exhaust
	Other index

Through the above target analyze, and then establish the evaluation index system of urban traffic sustainable development. The flow chart of establishing the index system is shown in Figure 2.

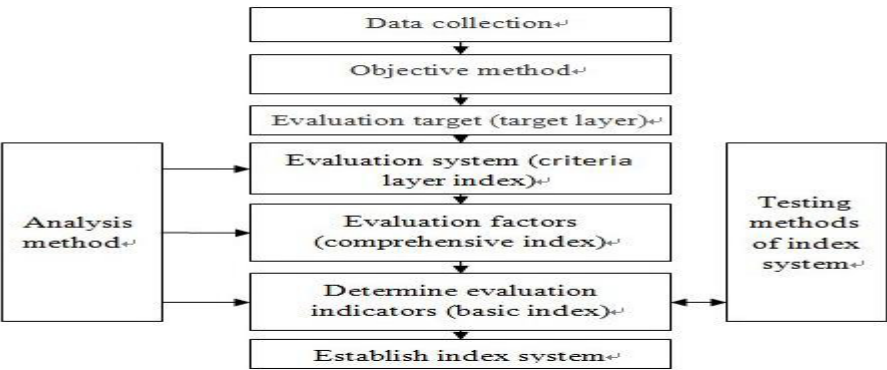


Fig. 2. The flow chart of establishing the index system

#### 4. Comprehensive evaluation on sustainable development of the urban traffic system

##### 4.1. Determine the weight of evaluation index

This paper combined with compatibility matrix analysis of the subjective weighting method to improve the entropy method, forming a kind of new combination assigning method. Its main idea: in the case of that the compatibility matrix analysis under the consistency conditions, considering subjective weight and objective weight, when subjective weight and objective weight have differences, adjusting their differences through a certain extent, making the combination weight more reasonable. This method not only can well reflect the decision makers' subjective intention, and make the weight coefficient more objective, but also avoid the weight completely depends on the experts' knowledge and experience as well as the unreasonable phenomenon of "the weight coefficient of important indicators are small and the weight coefficients of unimportant indicators are big". The steps are: firstly, find out the most reasonable subjective weight coefficient and objective weight coefficient, and then identify the proportion of subjective weight coefficients and objective weight coefficients according to the specific situation, and determine the adjustment ratio of adjusting their differences according to experts' opinions, and finally find out the comprehensive evaluation weight coefficients. Set the evaluation objects as  $\{A_i\} (i=1, 2, \dots, m)$ , the evaluation indexes  $\{X_j\} (j=1, 2, \dots, m)$  as,  $x_{ij}$  indicates the original value of the index  $j$  which belongs to object  $i$ , matrix  $(x'_{ij})$  is expressed as the proximity matrix of,  $x_{ij}$  the algorithm steps of calculating weights by improved entropy method are as follows.

- 1) Using 1-9 degree scale method to assign and constructing the judgment matrix  $A = (a_{ij})_{n \times n}$ ,  
 $(a_{ii}) = 1, (a_{ij}) = 1/a_{ji}$ ;
- 2) Using compatibility matrix method to obtain subjective weight  $w_j^{(s)}$ ;
- 3) Using entropy method to obtain objective weight  $w_j^{(o)}$ ;
- 4) Determine the proportion of subjective weight coefficients and objective weight coefficients  $\alpha_1 (0 < \alpha_1 < 1)$ ,  $\alpha_2 (0 < \alpha_2 < 1)$ , and adjustment coefficients  $\beta (0 < \beta < 1)$ , so the combined weight  $w_j$  of the  $j_{th}$  index expressed as:

$$\begin{aligned} w_j &= \alpha_1 w_j^{(s)} + \alpha_2 w_j^{(o)} + \beta (w_j^{(s)} - w_j^{(o)}) \\ &= (\alpha_1 + \beta) w_j^{(s)} + (\alpha_2 - \beta) w_j^{(o)} \end{aligned} \quad (1)$$

In formula:  $\sum_{j=1}^n w_j = 1, \alpha_1 + \alpha_2 = 1$

So the combined weight  $w_j$  of the  $j_{th}$  index expressed as:

$$w_j = (\alpha_1 + \beta) \frac{\sqrt[n]{\prod_{k=1}^n \sqrt[n]{\prod_{i=1}^n a_{jt} a_{tk}}} }{\sum_{s=1}^n \sqrt[n]{\prod_{k=1}^n \sqrt[n]{\prod_{i=1}^n a_{jts} a_{tks}}} } + (\alpha_2 - \beta) \frac{1 + \frac{1}{\ln m} \sum_{i=1}^m \frac{x'_{ij}}{\sum_{i=1}^m x_{ij}} \ln \frac{x'_{ij}}{\sum_{i=1}^m x_{ij}}}{\sum_{j=1}^n \left( 1 + \frac{1}{\ln m} \sum_{i=1}^m \frac{x'_{ij}}{\sum_{i=1}^m x_{ij}} \ln \frac{x'_{ij}}{\sum_{i=1}^m x_{ij}} \right)}$$

(2)

- 5) If the indicators in the  $k_{th}$  subsystem start from S and the subsystem contains  $n_k$  indicators, so the subsystem weight expressed as:

$$w_k = \frac{\sum_{j=s}^{s+n_k} w_j}{\sum_{j=1}^n w_j}$$

(3)

#### 4.2. Comprehensive evaluation model

- Comprehensive evaluation theory

At present, many scholars have been studied the issues of urban traffic sustainable development concept, strategy and development countermeasures. But, in the aspect of evaluation on sustainable development of the urban traffic system, there is only a little related research about the index analysis study. Besides, these research is only limited to the evaluation of sustainable development and in the absence of systematic comprehensive evaluation and analysis. Embarking from the system theory, this article researches and discusses the comprehensive evaluation theory and method of urban traffic system sustainable development according to the sustainable development theory.

Operation status of urban traffic system is the results of past, and also the future development starting point and basis. The comprehensive evaluation on sustainable development of urban traffic system is to analyze the structure and efficiency of urban traffic system, the environmental impact, the socio- economic adaptability and the resource utilization status, then to find out the problems, the crisis or opportunities in the process of the system development. So that decision makers can take measures according to this to ensure urban traffic system development harmonious and long-term, and to make lots of benefits as far as possible. To evaluate the sustainable development of urban traffic system, the specific work process as shown in figure 3.

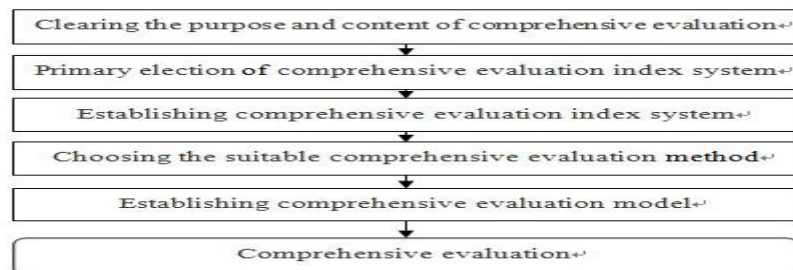


Fig. 3. The flow chart of urban traffic system sustainable development comprehensive evaluation

- Construction the evaluation model

- 1) Evaluation of subsystem development

After determining the evaluation object, using the index system combined with data collected, and calculation according to the improved entropy method which has been introduced before, can obtain the evaluation objects' evaluation value of traffic function, economic development, social stability and the environmental improvement in the evaluation period, each named for the traffic development index  $F_{1i}$ , economic development index  $F_{2i}$ , social development index  $F_{3i}$ , and environment development index  $F_{4i}$ , using them to describe the development status of city traffic function, economic development, social stability and environment improvement.

Development index of the  $i_{th}$  sample subsystem expressed as:

$$F_{ki} = \frac{\sum_{j=s}^{s+n_k} w_j}{\sum_{j=s}^{s+n_k} w_j} x'_{ij}$$

$$= \frac{\sum_{j=s}^{s+n_k} \frac{(\alpha_1 + \beta) w_j^{(s)} + (\alpha_2 - \beta) w_j^{(o)}}{\sum_{j=s}^{s+n_k} [(\alpha_1 + \beta) w_j^{(s)} + (\alpha_2 - \beta) w_j^{(o)}]} x'_{ij}}{1} (k = 1, 2, 3, 4) \quad (4)$$

In formula: s—Start label of each subsystems;

$n_k$ — Internal indicators number of each subsystem;

n— Indicators number contained in various subsystems.

- 2) Evaluation of sustainable coefficient

By weighted linear complicated method, the  $j_{th}$  index' evaluation value  $f_{ij} = w_j x'_{ij}$ , define the sustainable coefficient of the  $i_{th}$  sample according to formula (2):

$$S_i = \sum_{j=1}^n f_{ij} \left[ (\alpha_1 + \beta) \frac{\sqrt{\prod_{k=1}^n \prod_{i=1}^n a_{jt} a_{tk}}}{\sum_{s=1}^n \sqrt{\prod_{k=1}^n \prod_{i=1}^n a_{jts} a_{tks}}} + (\alpha_2 - \beta) \frac{1 + \frac{1}{\ln m} \sum_{i=1}^m \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \ln \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}}}{\sum_{j=1}^n \left( 1 + \frac{1}{\ln m} \sum_{i=1}^m \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \ln \frac{x'_{ij}}{\sum_{i=1}^m x'_{ij}} \right)} \right] x'_{ij} \quad (5)$$

In this paper the sustainable coefficient in the range of 0-1 is divided into three categories, according to the traffic sustainable development sustainable coefficient values from small to large, namely weakly sustainable traffic state, sustainable state and strong sustainable state, as shown in table 2.

Table 2. The classification table of sustainable coefficient of traffic sustainable development

Sustainable coefficient S	$0 \leq S \leq 0.5$	$0.5 \leq S \leq 0.8$	$0.8 \leq S \leq 1$
Sustainable state	Weakly sustainable	Sustainable	Strong sustainable

### 3) Evaluation of sustainable development coordinate coefficient

Sustainable development coordinate coefficient should reflect the coordinate development relationship between traffic development and society, environment and economy subsystem, standard deviation and average of each subsystem can be used. Define coordinate coefficient of sample i expressed as:

$$C_i = 1 - \frac{e_i}{f_i} = 1 - \frac{\sqrt{\frac{\sum_{g=1}^4 (F_{ki} - f_i)^2}{3}}}{f_i} \quad (6)$$

In formula:  $e_i$ —standard deviation of traffic development index, social progress index, environmental protection index and economic development index of sample i;

$f_i$ —average of traffic development index, social progress index, environmental protection index and economic development index of sample i.

In this paper the coordinate coefficient in the range of 0-1 is divided into four categories, according to the traffic sustainable development coordinate coefficient values from small to large, namely uncoordinated and unsustainable state, uncoordinated state, weakly coordinate state and coordinate state as shown in table 3.

Table 3. The classification table of coordinate coefficient of traffic sustainable development

Sustainable development coordinate	$C < 0$	$0 \leq C \leq 0.5$	$0.5 \leq C \leq 0.8$	$0.8 \leq C \leq 1$
coefficient C				
Coordinate state	Uncoordinated and unsustainable	Uncoordinated	Weakly coordinate	Coordinate

- Comprehensive evaluation

The sustainable coefficient of urban traffic sustainable development(S) and the coordination coefficient of urban traffic sustainable development (C) complete the comprehensive evaluation, which need to considerate the development level, speed and coordination of the urban traffic sustainable development (TSD). Expressed as:

$$TSD = TSD(S, C)$$

(7)

Construct a two-dimensional evaluation space by sustainable coefficient and coordinate coefficient of urban traffic sustainable development, in accordance with the regional division of the development sustainable coefficient and coordinate coefficient, this space can be divided into nine regions, as shown in Figure4.

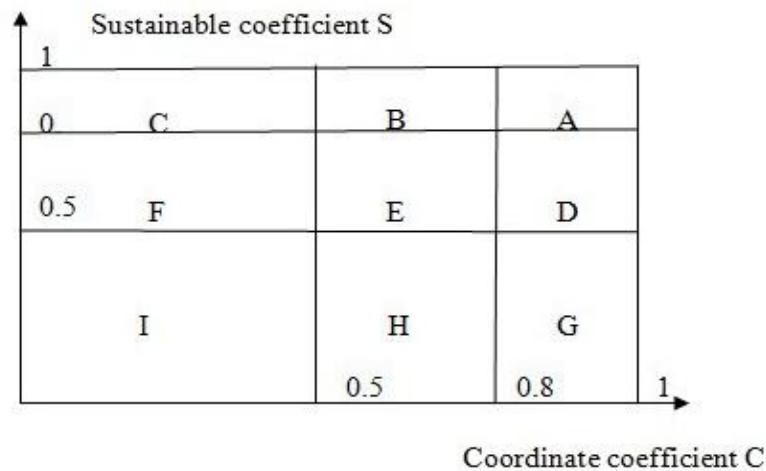


Fig. 4. The two-dimensional map of traffic sustainable development

Each area corresponds to the characteristics of urban traffic sustainable development, as shown in Table 4.

Table 4. The characteristics table of urban traffic sustainable development

Urban traffic sustainable development characteristics	Sustainable coefficient S	Coordinate coefficient C
Strong sustainable and coordinate development A	$0.8 \leq S \leq 1$	$0.8 \leq C \leq 1$
Strong sustainable and weakly coordinate development B		$0.5 \leq C \leq 0.8$



Strong sustainable and uncoordinated development C		$0 \leq C \leq 0.5$
Sustainable and coordinate development D		$0.8 \leq C \leq 1$
Sustainable and weakly coordinate development E	$0.5 \leq S \leq 0.8$	$0.5 \leq C \leq 0.8$
Sustainable and uncoordinated development F		$0 \leq C \leq 0.5$
Weakly sustainable and coordinate development G		$0.8 \leq C \leq 1$
Weakly sustainable and weakly coordinate development H	$0 \leq S \leq 0.5$	$0.5 \leq C \leq 0.8$
Weakly sustainable and uncoordinated development I		$0 \leq C \leq 0.5$

When  $C < 0.5$  there is a relatively large gap between the sample's traffic development index, economic development index, social development index and environmental development index, which represent that the city's four subsystems are uncoordinated, and the development deviate from the direction of the urban traffic sustainable development, showing unsustainable.

According to the position of the sample in the comprehensive evaluation chart, can easily determine the sample's sustainable features and draw an evaluation conclusion of sustainable development of samples, and then analyze the urban traffic development strategy. If the sample group is a collection of indicators of the different periods of the same city, the city's sustainable development path can be observed on a comprehensive evaluation chart.

## 5. Conclusion

Along with urbanization and fast development of economy, it is a serious problem that there are more traffic congestions, severe air pollutions and city noisy which has restricted the sustainable development of urban economy, society, environment and resources, therefore based on the sustainable development goal, evaluating the level of urban sustainable development, sustainability and coordination, analyzing the problems and causes faced by the urban sustainable development has great significance for resolving urban current serious traffic problems effectively. However, how to combine the sustainable development theory of city traffic system with comprehensive evaluation theory organically, in order to improve the city traffic system sustainable development ability and the overall traffic function, will be the long-term research topic.

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